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WATER SUPPLY AND WATER QUALITY CONTROL STUDY, NEMAHA RIVER BASIN (KANSAS AND NEBRASKA)

Public Health Service
Kansas City, Missouri

June 1964

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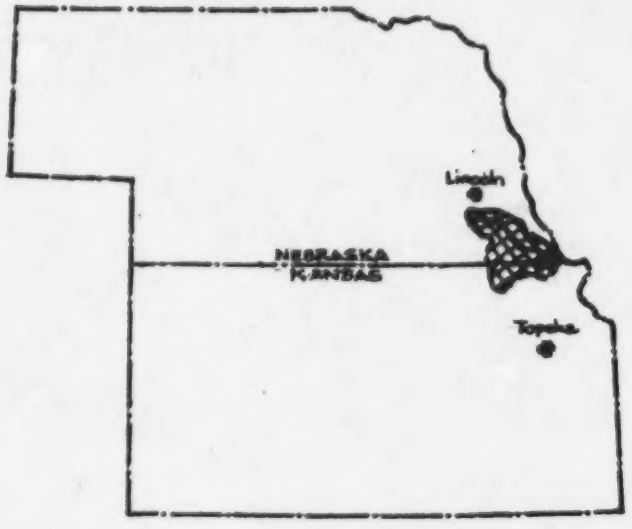
WATER SUPPLY AND WATER QUALITY CONTROL STUDY NEMAHA RIVER BASIN KANSAS AND NEBRASKA

Study of Potential Needs and Value of Water Storage for Municipal, Industrial, and Quality Control Purposes



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WATER SUPPLY AND WATER QUALITY CONTROL STUDY

NEMAHA RIVER BASIN
(Kansas and Nebraska)

Prepared for

DEPARTMENT OF THE ARMY

U. S. Army Engineer District

Kansas City, Missouri

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

JUNE 1964

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I. INTRODUCTION

Authority

In a letter dated August 12, 1963, the Kansas City District of the Corps of Engineers requested the Public Health Service, Region VI, Kansas City, Missouri, to make an investigation to determine the present and prospective needs for water for municipal and industrial uses and for water quality control in the Nemaha River Basin in Nebraska and Kansas.

This study has been made in accordance with the Memorandum of Agreement dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare relative to the Water Supply Act of 1958 (Title III of Public Law 85-500) and the Federal Water Pollution Control Act of 1956, both as amended by P.L. 87-88.

Purpose and Scope

The purpose of the study is to determine the need for and value of storage for municipal and industrial water supply and quality control in the Nemaha River Basin which is 1920 square miles and is located in southeast Nebraska and northeast Kansas. The study covers water storage needs and values during the 100-year study period, 1960 to 2060, as requested by the Corps of Engineers.

Acknowledgments

The cooperation of the following Federal, State, and local agencies which were contacted for information and assistance is gratefully acknowledged:

1. Corps of Engineers, Kansas City District, Kansas City, Missouri.

2. Kansas State Department of Health, Topeka, Kansas.

3. Kansas Water Resources Board, Topeka, Kansas.

4. Kansas State Geological Survey, Department of Oil and Gas, Lawrence, Kansas.

5. Nebraska State Department of Health, Lincoln, Nebraska.

6. Representatives of the municipalities in the basin.

II. SUMMARY AND CONCLUSIONS

Summary

1. The Corps of Engineers is making a study of the Nemaha River and tributaries to determine the feasibility of constructing multipurpose reservoirs. The multipurpose reservoirs are being considered for flood control, water supply, and water quality control.

2. The area studied is the Nemaha River basin located in southeastern Nebraska and northeastern Kansas including Gage, Johnson, Lancaster, Nemaha, Otoe, Pawnee, and Richardson Counties in Nebraska, and Brown, Marshall and Nemaha Counties in Kansas.

3. The area of the Nemaha basin is 1,920 square miles.

4. Population of the study area was 67,264 in 1960 of which 13,132 were urban and 54,132 were rural. County populations were used in the economic section.

5. The principal communities in the basin and their 1960 population are: Falls City, Nebraska - 5,598; Tecumseh, Nebraska - 1,887; Pawnee City, Nebraska - 1,343; Humboldt, Nebraska - 1,322; Hiawatha, Kansas - 3,391; Sabetha, Kansas - 2,318; and Seneca, Kansas - 2,072.

6. Average daily 1963 water use from municipal water supplies in the basin amounts to 2.675 million gallons per day (mgd) supplying a population of 21,923 for an average per capita use of 122 gallons per capita per day (gpcd).

7. The estimated wastes produced are: 1,550 population equivalent (P.E.) at Tecumseh, 5,500 P.E. at Falls City, 1,300 P.E. at Pawnee City, 1,300 P.E. at Humboldt, 1,300 P.E. at Sabetha, and 2,000 P.E. at Seneca.

Conclusions

1. The urban population in the six-county study area, used for economic projections, will increase from a population of 13,132 persons in 1960 to 26,000 persons by 2010 and 40,000 persons by 2060. The total population will increase from a population of 67,264 persons in 1960 to 68,000 persons by 2010 and 80,000 persons by 2060.

2. Based on economic projections the municipal and industrial water demands in the study area will be 5 mgd in 2010 and 10 mgd in 2060.

3. During the study period the municipal and industrial water demands can be met either from present sources or by development of existing water sources.

4. There is no value for water storage to meet municipal and industrial demand, since present projections based on present information indicates that there is no need from the proposed reservoirs.

5. The streams receiving sewage plant effluents from Seneca and Sabetha, Kansas, are the only streams in the basin that will not have sufficient streamflow for quality maintenance without regulation. Sabetha effluent discharges to Pony Creek and Seneca discharges to South Fork Nemaha River.

6. To maintain satisfactory water quality (a minimum of 5 ppm dissolved oxygen) below Seneca, a maximum annual draft on storage of 700 acre-feet above natural inflows will be required by 2060.

7. The annual value of benefits attributable to storage for quality control of Seneca wastes is $1,440. Costs were discounted from the year of first need, 2000 to 1960.

8. To maintain satisfactory water quality below Sabetha, a maximum annual draft on storage of 1,500 acre-feet will be required by 2060.

9. The annual value of benefits attributable to storage for quality control of Sabetha wastes is $16,200. The year of first need is 1960.

10. Streamflow regulation from the proposed reservoirs will not improve the water quality in Pony Creek and South Fork Nemaha River at Sabetha and Seneca since these municipalities are not located downstream from the proposed reservoirs.

11. Maintenance of satisfactory water quality below the proposed reservoir will provide widespread benefits to a full spectrum of water uses in the study area. By 2060, 100,000 people will live in the area which will benefit through streamflow regulation by the improvement of water quality in approximately 250 river miles of stream in the basin. Municipal and industrial raw water supplies of satisfactory quality will be available. Recreational opportunities, including fishing, swimming, water skiing, and boating will be increased. The esthetic values of the stream stemming from clean surface waters, a satisfactory public health water environment, and preservation of property values in areas contiguous to the stream will thereby be assured.

III. DESCRIPTION OF PROJECT

Location

Six reservoirs are being considered by the Corps of Engineers in the Nemaha River basin. Five of the sites are in Nebraska and one in Kansas near the Nebraska-Kansas state line. See Map of Study Area in Section IX.

Streamflow

The channel capacity at the Falls City gage on the Nemaha River is 14,000 second-feet. Upstream, where natural and improved channel sections are involved, channel capacity varies greatly. Observations show that the improved channels have a capacity about 75 percent greater than that of adjoining unimproved channel sections. 12/

Records of the Nemaha River for the station at Falls City, Nebraska, (drainage area 1,340 square miles) show that flow measurements have ranged between 51,400 and 4.3 cfs with the mean flow for the 18 years of record being 664 cfs. Historical streamflows in the basin are presented in Exhibit No. 1.

Water Quality

There are no long range chemical quality records of surface waters in the Nemaha River basin. Nine samples of Nemaha River water collected near Falls City, Nebraska in 1961 had the following concentrations: Alkalinity - 148 to 316 mg/l, total hardness - 60 to 304 mg/l, and conductivity - 388 to 952 micromhos/cm. The streamflows during sampling varied from a low of 131 cfs to a high of 3,400 cfs.

Pertinent Data [10/]

As shown in the 1947 Corps of Engineers' report, the six proposed reservoirs would control a total area of 464 square miles. Storage space data for the proposed recervoir is shown in Table No. III-1. The silting allocation made by the Corps of Engineers was based on a period of 50 years.

Table No. III-1

Reservoir Data

Nemaha River Basin (Nebraska and Kansas)

Reservoir	Stream (Creek)	Drainage Area (Square Miles)	Storage Allocation (Acre-Feet) Flood Control	Silt	Total
Stella	Little Muddy	48	18,100	2,400	20,500
Auburn	Muddy	57	22,150	2,850	25,000
Dubois	Turkey	195	52,500	9,700	62,200
Humboldt	Long Branch	63	23,500	3,100	26,600
Tecumseh	Yankee	54	20,300	2,700	23,000
Sterling	Baker	47	17,650	2,350	20,000
	TOTALS	464	154,200	23,100	177,300

Watershed Work Plans

Reports made by the Soil Conservation Service on watershed work plans in the Nemaha River basin are shown below:

Watershed Project	State	Counties	Drainage Area (Acres)
1. Rock Creek	Nebraska	Pawnee	9,600
2. Upper Big Nemaha	Nebraska	Gage, Johnson, Lancaster and Otoe	119,600
3. Walnut Creek	Nebraska Kansas	Richardson, Brown	80,394

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The Nemaha River is tributary to the Missouri River and is located in southeastern Nebraska and northeastern Kansas. The total area of the drainage basin is 1,920 square miles with 1,315 square miles in Nebraska and 605 square miles in Kansas.

The principal tributaries to the Nemaha River are the North Fork Nemaha River and the South Fork Nemaha River.

The study area is defined as those portions of the Nemaha River basin that are located in parts of Gage, Johnson, Lancaster, Nemaha, Otoe, Pawnee, and Richardson Counties in Nebraska, and Brown, Marshall and Nemaha Counties in Kansas.

Geography and Topography

The Nemaha River basin is marked by a highly developed dendrite pattern and comparatively wide flood plains, particularly in the lower part of the basin. The headwaters regions reach elevations of 1,470 feet mean sea level and the mouth of the river is at about 852 feet. River slopes vary from 2 feet per mile in the lower reaches to over 20 feet per mile in the upper reaches.

Climate

The climate of the basin is characterized by hot summers and moderately cold winters. The mean annual temperature in the basin is about

52°F with extremes of approximately 109°F and -28°F. The average frost-free growing has a duration of approximately 169 days. The average annual rainfall is about 31 inches.

Principal Communities

The principal communities in the study area and their 1960 population are: Falls City, Nebraska - 5,598, Tecumseh, Nebraska - 1,887, Pawnee City, Nebraska - 1,343, Humboldt,Nebraska - 1,322, Hiawatha, Kansas -3,391, Sabetha, Kansas - 2,318, and Seneca, Kansas - 2,072.

V. ECONOMY

An assessment of future municipal and industrial, and quality control water requirements in the Nemaha River Basin involves an appraisal of the area's future industrial and population growth potential. The increasing regional and national demands for goods and services affords an opportunity for attracting new industries and expanding existing ones. However, prospect for growth in the Nemaha River Basin depends on its competitive advantages over other areas.

To facilitate the use of existing economic data, the entire counties of Pawnee, Johnson and Richardson, Nebraska, and Brown, Marshall, and Nemaha, Kansas, are considered as the study area in this section of the report.

Past and Present

In 1960, the economy of the Nemaha study area was dependent on services (construction, transportation, communications, utilities, retail and wholesale trade, public administration, government and personal services), agriculture, manufacturing and mining in that order of importance. Of the 25,891 persons in the total labor force, about 14 thousand or 54 percent were employed in the services, 9,330 or 36 percent were employed in agriculture and about 1,800 or 7 percent were employed in manufacturing. Less than one percent was employed in the mining category and the remaining three percent of the total labor force was unemployed. Employment trends are shown in Table No. V-1.

Table No. V-1

The Number and Percentage of the Labor Force 1/
By Major Classifications
Nemaha River Basin Study Area

1950 - 1960

	1950		1960		1950 - 1960
	Number	Percent of Labor Force	Number	Percent of Labor Force	Percent Change
Farm	13,784	46	9,330	36	-32
Mining	158	--	40	--	-75
Manufacturing	1,060	4	1,819	7	+72
Total Services	14,415	48	13,999	54	- 3
Unemployed	431	2	703	3	+63
Total Labor Force	29,848	100	25,891	100	-13
Total Population	77,799	--	67,264		-14

Agriculture is the most important segment of the economy when measured by the dollar returns based on farm products sold. The study area is highly productive in beef and dairy farming. It is also one of the most productive dryland farming areas in the plain states. In 1959, the dollar return from farm products sold was almost $75 million. This was an increase of about $15 million over the 1949 dollar return or 27 percent (adjusted to the 1959 value of the dollar). During this period, agricultural employment decreased about 30 percent from an estimated 14,000 to about 9,500. Farm consolidation, intensive crop production and farm mechanization was primarily responsible for the increasing farm income and decreasing farm employment. Refer to Table No. V-2 for agricultural trends in the study area.

Table No. V-2

Agricultural Trends [3/]

Nemaha River Basin Study Area

1949 - 1954 - 1959

	Number Farms	Cropland Harvested Acres	Value of Crops Sold (Million $)	Value of Livestock & L.S. Products Sold (Million $)	Value of all Farm Products Sold (Million $)
1949	10,035	1,187,879	17.8	41.5	59.3
1954	9,214	1,197,219	26.6	35.1	61.7
1959	8,054	1,161,610	26.8	48.0	74.8

The importance of manufacturing to the economy of the study area has been increasing. Employment in this category increased from 1060 in 1950 to 1819 in 1960. About 70 percent of this increase was in the food and kindred products, and fabricating metals categories. Table No. V-3 depicts manufacturing employment trends.

Table No. V-3

Manufacturing Employment Trends [1/]

Nemaha River Basin Study Area

1950 - 1960

	1950	1960	Percent Change 1950-1960
Manufacturing	1060	1819	+72
Fabricating Metals	229	479	+109
Food and Kindred Products	469	743	+58
Textile and Apparel	55	236	+329
Printing and Publishing	203	254	+25
Other Manufacturing	104	107	+3

The number of establishments and value added by manufacturers has also shown increases, indicating new manufacturing industries developing in the study area. Refer to Table No. V-4 for manufacturing trends.

Table No. V-4

Manufacturing Trends 2/

Nemaha River Basin Study Area

1954 - 1958

	Number of Establishments	Value Added by Mfg. ($1,000)*
1954	58	6,895
1959	65	8,433

*Adjusted to the 1959 value of the dollar.

Petroleum, gypsum, stone, sand and gravel are the only known minerals of commercial value located in the study area. Employment in mining decreased substantially from 158 in 1950 to 40 in 1960. The depletion of petroleum in the area has been primarily responsible for this decrease in employment. 4/

The total population of the study area has decreased about 35 percent, from 102,483 in 1910 to 67,264 in 1960. During this period, the rural portion decreased from 92,654 to 54,132, while the urban portion increased from 9,829 to 13,132. The out-migration of the farm labor force to the surrounding more industrial urban areas was primarily responsible for the decrease in rural population. Table No. V-5 depicts population data for the study area.

Table No. V-5

Population Trends for the 5/

Nemaha River Basin Study Area

1910 - 1960

	1910	1920	1930	1940	1950	1960
Urban	9,829	15,209	17,151	16,311	13,363	13,132
Rural	92,654	84,443	83,206	75,185	64,436	54,132
TOTAL	102,483	99,652	100,357	91,496	77,799	67,264

Future

The economy of the study area has been undergoing a change from a predominately agricultural economy to a better balanced industrial-agricultural one. This pattern is expected to continue. Projected population growth 1/ in the study area should affect the study area in terms of increased manufacturing and agricultural production. 6,7,8,9/ Refer to Table No. V-6 for employment projections.

Agriculture is expected to continue to make up a large portion of the future income of the study area. However, a continued increase in farm technology will achieve this high rate of production with a decreasing farm labor force. The farm labor force is expected to decrease to 8,000 in 2010 and 7,000 in 2060.

Manufacturing employment in the study area is projected to increase from about 1,800 in 1960 to 2,500 in 2010 and 4,100 in 2060. The most significant increases should be in the categories of food and kindred products and fabricated metals and machinery.

The change from a predominately agricultural type economy to a more diversified agricultural-industrial type is expected to reverse

the downward population trend. This change is expected to increase employment in the manufacturing and service categories, and support a larger population throughout the study area. The total population in the study area is expected to reach 68,000 in 2010 and 80,000 by 2060. The urban portion (including all urban in 1960 and municipalities that are expected to be urban in the future) is expected to increase to 26,000 by 2010 and 40,000 in 2060. The rural portion is expected to continue to decrease to about 42,000 in 2010 and about 40,000 in 2060. Exhibit No. 2 displays population projections for the study area. [6,7,8,9/]

Table No. V-6

Projected Employment of the Labor Force

Nemaha River Basin Study Area

	1960	2010		2060	
	Number	Number	Percent of Labor Force	Number	Percent of Labor Force
Farm	9,330	8,000	31	7,000	23
Manufacturing	1,819	2,500	10	4,100	14
Total Service	13,999	14,500	56	18,000	59
Unemployed	703	1,000	4	1,200	4
Total Labor Force	25,891	26,000	100	30,400	100
Total Population	67,264	68,000		80,000	

Projected population and industrial growth will be accompanied by an increase in municipal and industrial water needs and a corresponding increase in waste discharges. The effect on water supply and water quality control needs is covered in the following section.

VI. WATER RESOURCES

Surface Water

There are four streamflow gaging stations in the Nemaha basin. The Seneca, Kansas, gaging station (drainage area- 276 square miles) is located on Turkey Creek, two miles downstream from Clear Creek, five miles upstream from the Nemaha River, and eight miles northwest of Seneca. During the 14 years of record (1948-1962) there were periods of no flow at times in 1956 and 1957. The maximum discharge was 18,000 cfs and the average discharge during the 14 years of record was 153 cfs.

The Humboldt, Nebraska, gaging station (drainage area - 531 square miles) is located on North Fork Nemaha River, 800 feet downstream from Long Branch Creek on the edge of Humboldt. During the 10 years of record (1952-1962) the minimum recorded daily flow was 6.2 cfs on August 8 and 9, 1957. The maximum discharge was 51,000 cfs and the average discharge during the 10 years of record was 207 cfs.

The Verdon, Nebraska, gaging station (drainage area - 188 square miles) is located on Muddy Creek, 0.4 mile west of Verdon and one mile downstream from Sardine Creek. During the 10 years of record (1952-1962) the minimum recorded daily flow was 1.0 cfs on December 1, 1956. The maximum discharge was 31,900 cfs and the average discharge during the 10 years of record was 84.2 cfs.

The Falls City, Nebraska, gaging station (drainage area - 1,340 square miles) is located on the Nemaha River, one mile south of Falls City and 13 miles upstream from the mouth. During the 18 years of record (1944-1962) the minimum daily discharge was 4.3 cfs, December 15 and 16, 1953. The maximum discharge was 51,400 cfs and the average

discharge during the 18 years of record was 664 cfs.

There are no long range chemical quality records of surface waters in the Nemaha River basin. Nine samples of Nemaha River water collected near Falls City, Nebraska, in 1961 had the following concentrations: Alkalinity - 148 to 316 mg/l, total hardness - 60 to 304 mg/l, and conductivity - 388 to 952 micromhos/cm. The streamflows during sampling varied from a low of 131 cfs to a high of 3,400 cfs. 13/

Ground Water

Ground water in the Nemaha River basin is obtained from both deep and shallow wells. Shallow wells are used in obtaining water from alluvial deposits and glacial drift.

The rocks of the Permian and Pennsylvanian systems in the deep wells yield some water but are not as productive as the alluvial deposits and glacial drift.

The water supply for Bern, Kansas, is an example of a deep well supply with total dissolved solids 468 mg/l, sulfates 44 mg/l, hardness 314 mg/l, and chlorides 13 mg/l.

The water supply for Falls City, Nebraska, is obtained from alluvial deposits near the Missouri River south of Rulo, Nebraska. The results from analyses of a water sample from this supply were total dissolved solids 220 mg/l, sulfates 104 mg/l, hardness 168 mg/l, and chlorides 18 mg/l.

The chemical quality of ground water is generally satisfactory for municipal and industrial water uses. Chlorides range from .18 to 251

milligrams per liter (mg/l), sulfates from 12 to 322 mg/l, total dissolved solids from 220 to 1,062 mg/l, and hardness from 168 to 1,600 mg/l as $CaCO_3$. Chemical analyses of the water supplies are shown in Exhibit No. 4.

VII. MUNICIPAL AND INDUSTRIAL WATER SUPPLY NEEDS

Present

Twenty-three water supply facilities in the Nemaha River Basin serve approximately 22,000 persons with an average of 2.7 million gallons per day (mgd). The average water demand from these facilities is 122 gallons per capita per day (gpcd). Details of municipal demands are shown in Exhibit No. 3 of the Appendix.

Twenty-two municipalities have ground water supplies and one, Sabetha, Kansas, has a treated surface water supply from an impoundment.

In most cases, the mineral concentrations of the water supplies are less than those stated in the 1962 Public Health Service Drinking Water Standards (values not to be exceeded). A chloride concentration of 251 milligrams per liter (mg/l) for Dawson Well #1 is the only water supply exceeding the stated limit of 250 mg/l. The sulfate concentrations vary from a low of 12 mg/l to a high of 322 mg/l for one well at Humboldt, Nebraska. Several of the water supplies contain total dissolved solids concentrations near or above the stated limit of 500 ppm. The total dissolved solids concentrations vary from a low of 220 mg/l to a high of 1,062 mg/l for well No. 2 at Panama, Nebraska.

Prospective

The increase in municipal and industrial water requirements during the study period is based on population growth, industrialization, commercialization, and development of new water-using devices for the home. The study area is expected to have a steady light industrial and commercial growth.

Table No. VII-1 indicates the expected water use in gpcd (gallons per capita per day). The figures include light water-using industries and commercial establishments.

Table No. VII-1

Water Demands
(gpcd)

Nemaha River Basin (Nebraska and Kansas)

YEAR	GPCD
1963	122
2010	160
2060	200

The municipal and industrial demands for the study area are expected to reach 4.8 mgd by 2010 and 10 mgd by 2060.

The larger communities in the study area are: Falls City, Nebraska (1960 population 5,598); Hiawatha, Kansas (1960 population 3,391); Sabetha, Kansas (1960 population 2,318); Seneca, Kansas (1960 population 2,072); Tecumseh, Nebraska (1960 population 1,887); Pawnee City, Nebraska (1960 population 1,343), and Humboldt, Nebraska (1960 population 1,322).

Falls City, Nebraska, has 10 wells south of Rulo, Nebraska, near the Missouri River. Hiawatha, Kansas, is on the basin boundary and gets part of its water supply from outside the basin. The Hiawatha, Kansas, water supply comes from both wells and springs. Sabetha, Kansas, uses water from an impounded reservoir. Seneca, Kansas, has both springs and wells. Tecumseh, Nebraska, gets its water supply from three wells. Pawnee City uses water from three wells. Humboldt, Nebraska, has three wells and

one spring and is developing a new well field. All of the other communities in the study area have population of less than a thousand persons each. All of these communities use wells as their source of water supply.

Present information indicates that all of the municipalities in the study area either have adequate water supplies or will have adequate supplies when planned improvements have been completed. (Humboldt, Nebraska, is developing a new well field.)

Value of Storage

Projections based on present information indicates that there is enough water available to meet projected municipal and industrial water demands. There is no need for or value of storage for municipal and industrial water in the Nemaha River basin.

VIII. STREAMFLOW REGULATION FOR WATER QUALITY CONTROL

General

Under provisions of the Federal Water Pollution Act, Public Law 84-660, as amended by P.L. 87-88, in the survey or planning of a reservoir by any Federal agency, consideration must be given to the inclusion of storage for regulation of streamflow for the purpose of water quality control. The law expressly states that any such storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling wastes at their sources.

Discharge of wastes, even when treated to the maximum economically feasible and practical limit, will cause an unsatisfactory quality condition in receiving waters whose waste assimilation capacity is exceeded. This condition usually, but not always, occurs during periods of low flows and may be avoided by regulation to maintain flows at higher levels. Recognition must be given to the need for required flows in receiving streams if the water quality is to be maintained at acceptable levels.

The quality objectives are based on total dissolved solids (TDS), sulfates (SO_4), chlorides (Cl), and dissolved oxygen (DO). The limits for TDS, SO_4, and Cl are those stated in the 1962 Public Health Service Drinking Water Standards of not greater than 500, 250, and 250 mg/l, respectively. The DO objective of 5 mg/l is used in accordance with the objectives of the Missouri Basin Engineering Health Council.

Basic data indicating the present sources of domestic and industrial pollution appear in the Appendix as Exhibit No. 5.

Present

Based on projected economic activity and limited surface water analyses, mineral solids concentrations of the surface water will continue to meet the U.S. Public Health Service Drinking Water Standards and water quality control to maintain these objectives will not be required. (Note: In the absence of allocation of storage for irrigation, no consideration has been given to the effects of irrigation return flows on water quality.)

As population increases, so will waste loadings discharged. With adequate treatment, which is defined in this study as 85 percent removal of biochemical oxygen demand, waste residuals reaching the major rivers do not exceed their assimilative capacities in the first year of the study period (1960). Pony Creek which receives Sabetha's waste is the only river or creek in the basin whose assimilative capacity is exceeded in 1960.

Prospective

Future waste loadings in the Nemaha River basin have been estimated on the basis of population projections and on the projected increase in municipal water demands. Recreation uses are not expected to affect water quality. It is assumed that all municipalities will have adequate treatment. Table No. VIII-1 presents the main factors use in estimating

the future pollution loads in the study area.

Table No. VIII-1

Waste Loading Projection Factors

Nemaha River Basin (Nebraska & Kansas)

Item	1960	2010	2060
Municipal Water Demand (GPCD)	125	160	200
Municipal Return (percent)	70	70	70
Organic Load per Population Equivalent (pounds ultimate first stage BOD)	0.25	0.25	0.25
BOD Removal Efficiency (percent)	85	85	85

The pollutional effect of waste discharges on a receiving stream is a function of a number of variables. The main assumptions used in evaluating quality control requirements in the Nemaha River basin are enumerated below:

1. Characteristic of waste discharged to the stream will continue to be primarily organic in nature.

2. Specific mineral and/or organic toxicants will not be a significant problem.

3. Maintenance of a minimum concentration of 5 mg/l dissolved oxygen will provide reasonable protection for fish and other aquatic life and is in accordance with the objectives of the Missouri Basin Engineering Health Council.

4. Quality control needs were based on three different periods. The summer period is assumed to be five months long and to have an

average water temperature of 24° C. The winter period is assumed to be four months long and to have an average water temperature of 5° C. The spring and fall periods are assumed to be three months long and to have an average water temperature of 15° C.

5. Streamflow regulation requirements are based on the assumption that the water released from a reservoir for quality control will have an oxygen content equal to or greater than the oxygen content of the natural streamflow at 80 percent saturation.

Quality control needs were determined for the streams for the summer, winter, and spring and fall seasons. The graphical solution of the oxygen-sag equation was used to determine the flow regulation required. 14/ It was determined that streamflow regulation for quality control was needed in South Fork Nemaha River below Seneca, Kansas, and in Pony Creek below Sabetha, Kansas. The table below gives the minimum flows required in the stream to meet the quality requirements at Seneca and Sabetha, Kansas.

Table No. VIII-2

Minimum Streamflow for Quality Control
(mgd)
Nemaha River Basin (Nebraska & Kansas)

Municipality	1960			2010			2060		
	Summer	Spring & Fall	Winter	Summer	Spring & Fall	Winter	Summer	Spring & Fall	Winter
S. Fork Nemaha Seneca	< 1	< 1	< 1	1.5	< 1	< 1	3	2	1
Pony Creek Sabetha	< 1	< 1	< 1	1.0	< 1	< 1	2	1	< 1

Considering the needs for water and cost of providing this water, a 90 percent protection level or a recurrence interval of 10 years is used. Taking into account the quality control needs, municipal returns, and natural runoff, Table No. VIII-3 lists the maximum annual draft on

storage* needed in 2060 to maintain the quality objectives in the reaches below Seneca and Sabetha, Kansas. A schematic diagram of the river systems is shown in Figure No. VIII-1.

Table No. VIII-3

Net Regulation Requirements in Acre-Feet Per Year in 2060
Nemaha River Basin (Nebraska and Kansas)

Stream	Draft on Storage
South Fork Nemaha River (below Seneca)	700
Pony Creek (below Sabetha)	1,500

The drafts on storage shown in Table No. VIII-3 are those required to meet the quality objectives in South Fork Nemaha River and Pony Creek. There is a need for quality control water in South Fork Nemaha River by 2000. Below Sabetha, Kansas, (Pony Creek), there is a need for water for quality control in the beginning of the study period (1960). However, there are no reservoirs planned for these tributaries. The area adjacent to the tributaries below Seneca and Sabetha are sparsely populated with no major communities. No municipal or industrial uses are expected in these areas.

*Annual draft on storage is the sum of the incremental excesses of needed releases over inflows during a climatic year.

Benefits

The population of the area in which benefits will be made available is estimated to be approximately 100,000 by 2060. Benefits attributable to storage for streamflow regulation for water quality control will be widespread in scope and may be tangible, i.e., may have a measurable dollar value or may be intangible with no measurable dollar value.

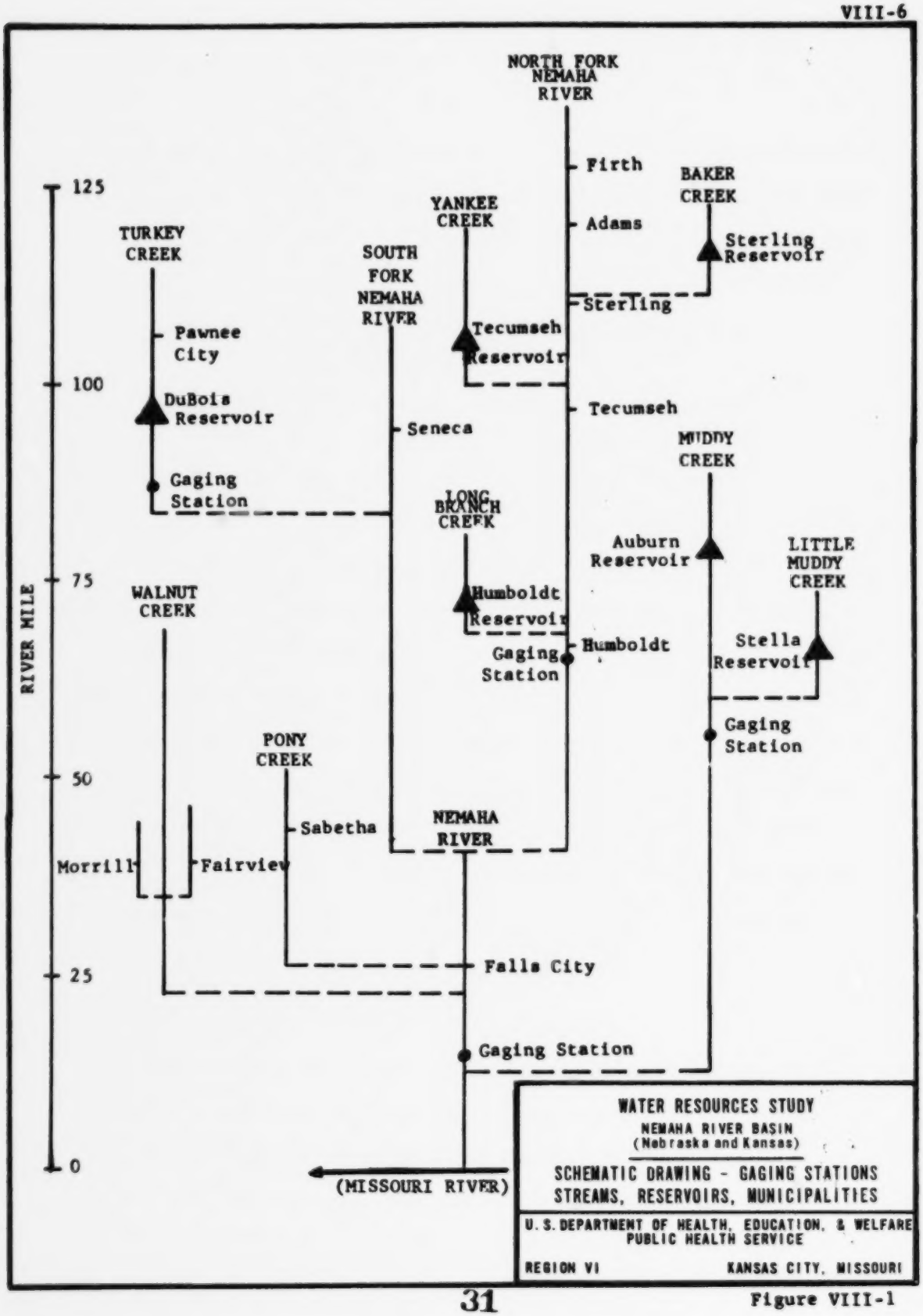


Figure VIII-1

Representing the latter, water quality control below the proposed reservoirs would provide recreational opportunities for a distance of approximately 250 river miles. Recreational opportunities, including fishing, swimming, water skiing, and boating will be increased. The esthetic values of the stream stemming from clean surface waters, a satisfactory public health water environment, and preservation of property values in areas contiguous to the stream will thereby be assured.

Value of Benefits

When no adequate means can be devised to evaluate directly the economic effects of water quality maintenance or improvement, the cost of achieving the same results by the most likely alternative may be used as an approximation of value. In determining the "most likely alternative" several possibilities have been studied.

At Seneca, Kansas, the most feasible alternative is a holding pond which will be needed by the year 2000. The holding pond would be used to hold the sewage plant effluent. Releases from the holding pond to the receiving stream can be made at a rate not to exceed the assimilative capacity of the receiving stream. The holding pond will have an area of 30 acres and a depth of 10 feet. The annual value for the alternative at Seneca, Kansas, is $1,440 for the duration of the study period, 1960 to 2060. See Exhibit No. 6.

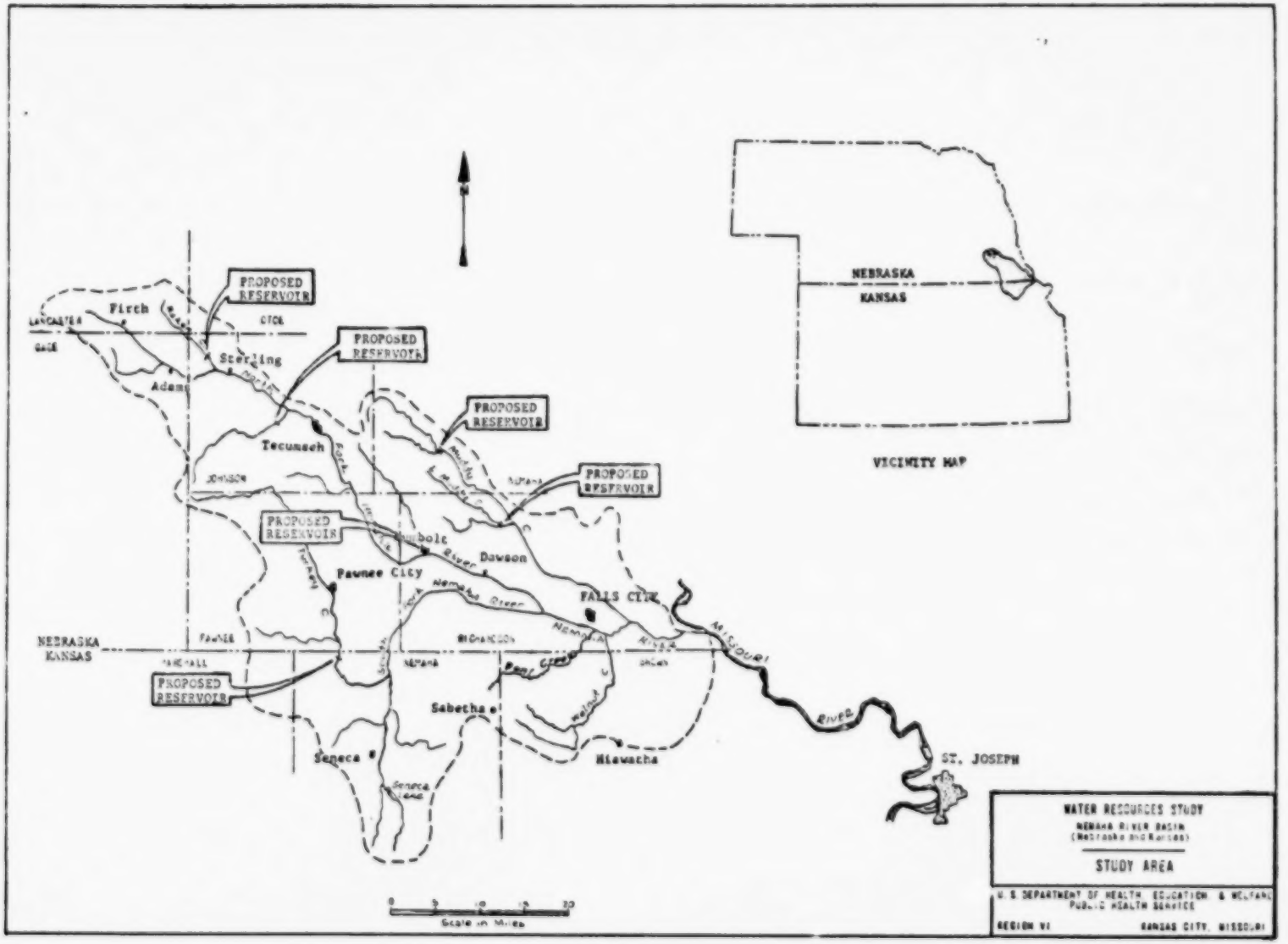
At Sabetha, Kansas, a six-inch pipeline and pumps will be needed in the beginning of the study period to transport the sewage plant

effluent to the mouth of the South Fork Nemaha River. An eight-inch pipeline will be needed by 2010. A fifty-year life for each of the pipelines, a pumplife of 25 years, and an annual operation and maintenance cost of $3,000 was used.

The annual value of the alternative at Sabetha, Kansas, is $16,200 for the duration of the study period, 1960 to 2060. See Exhibit No. 6.

The location of proposed reservoirs precludes use of releases to improve the water quality in Pony Creek and South Fork Nemaha River at Sabetha and Seneca. See map of the area in Section IX. Releases from the proposed reservoir on Turkey Creek would be beneficial in Turkey Creek and below its confluence with the South Fork Nemaha River. Regulated flow in the Nemaha River at its confluence with Pony Creek can assure satisfactory quality conditions downstream.

IX. MAP OF AREA


PROPOSED RESERVOIR
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PROPOSED RESERVOIR
PROPOSED RESERVOIR
Firth
Sterling
Adams
Tecumseh
Pawnee City
Dawson
FALLS CITY
Sabetha
Seneca
Hiawatha
ST. JOSEPH
NEBRASKA
KANSAS
MISSOURI RIVER
Scale in Miles
NEBRASKA
KANSAS
VICINITY MAP
WATER RESOURCES STUDY
NEMAHA RIVER BASIN
(Nebraska and Kansas)
STUDY AREA
U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI
KANSAS CITY, MISSOURI

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XI. APPENDIX

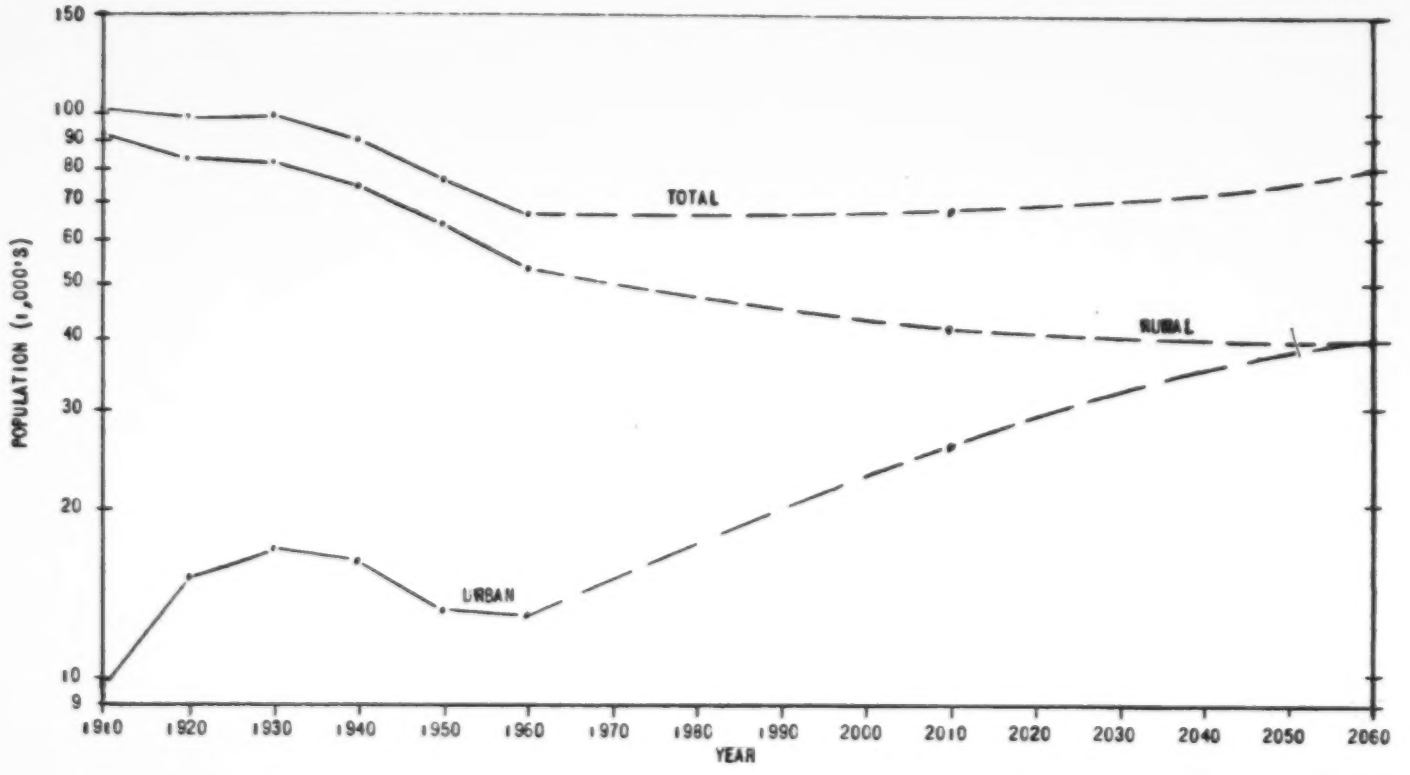
Exhibit No. 1

Historical Streamflows [11,12]

Nemaha River Basin Study Area (Nebraska and Kansas)

Station	Location	River Mile*	Years of Record	Flows in cfs		
				Maximum	Minimum	Average
Turkey Creek near Seneca, Kansas	2 miles downstream from Clear Creek and 5 miles upstream from the Nemaha River	5	14	18,000	0	153
North Fork Nemaha River at Humbolt, Nebraska	800 feet downstream from Long Branch Creek	27	10	51,000	6.2	207
Muddy Creek at Verdon, Nebraska	0.4 mile west of Verdon and 1 mile downstream from Sardine Creek	42	10	31,900	1.0	84.2
Nemaha River at Falls City, Nebraska	1 mile south of Falls City and 13 miles upstream from the mouth	13	18	51,400	4.3	664

*River miles are approximate



WATER RESOURCES STUDY

NEMAHA RIVER BASIN
(Nebraska and Kansas)

POPULATION PROJECTIONS

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE

REGION VI KANSAS CITY, MISSOURI

EXHIBIT NO. 2

Exhibit No. 3

Municipal Water Supplies [15/]

Nemaha River Basin Study Area (Nebraska & Kansas)

Municipality	1960 Population	1963 Population Served	Water Treatment	Source of Supply	Maximum Dependable Draft (mgd)	Average Output (mgd)	GPCD
NEBRASKA							
Adams	387	370	None	2 wells	.17	.038	102
Dawson	263	240	None	2 wells	.173	.009	37
Dubois	218	212	None	3 wells	0.140	.005	24
Elk Creek	170	170	None	2 wells	0.036	0.010	59
Falls City	5,598	5,590	Aeration, Coagulation, Chlorination, Softening	10 wells	2.40	0.780	140
Firth	277	287	None	1 well	0.140	0.030	104
Humboldt	1,322	1,322	None	3 wells, 1 spring	0.115	0.150	113
Panama	155	150	None	2 wells	0.0144	0.004	27
Pawnee City	1,343	1,342E	Aeration, Chlorination	3 wells	0.216	0.110	82
Salem	261	235	None	2 wells	.072	0.025	106
Stella	262	240	None	1 well	0.140	.030	125
Shubert	231	210	None	2 wells	.094	0.002E	100E
Sterling	471	450	None	2 wells	0.140	.045	100
Table Rock	422	390	None	2 wells	.058	0.035	90
Tecumseh	1,887	1,870	None	3 wells	1.11	0.536	287
Verdon	267	240	None	1 well	0.173	.008	33
KANSAS							
Bern	206	190	Chlorination, Stabilization	2 wells	-	0.008	42
Corning*	240	200	Chlorination, Stabilization	Well	-	0.010	50
Hiawatha**	3,391	3,200	Chlorination	Springs & Wells	-	0.300	94
Morrill	299	325	Chlorination	2 wells	-	0.020	62
Reserve	138	130	Chlorination	Well	-	0.020	154
Sabetha	2,318	2,400	Aeration, Coagulation Chlorination, Filtration	Impounded Reservoir	-	0.300	125
Seneca	2,072	2,160	Chlorination, Fluoridation	Spring & Wells	-	0.200	93
TOTALS		21,923				2.675	122

* Source of water supply not in Nemaha River Basin
**Part of water supply source in Nemaha River Basin

Exhibit No. 4

Typical Chemical Analyses of Water Resources [15/]
(Results in Milligrams per Liter, mg/l)

Nemaha River Basin Study Area (Nebraska & Kansas)

Location	Type*	Total Dissolved Solids	Chlorides (Cl^-)	Sulfates ($SO_4^=$)	Nitrate (NO_3^-)	Hardness ($CaCO_3$)	Iron (Fe)	Remarks
NEBRASKA								
Adams	M-R	460	20	52	<10		<0.05	Well #1
		400	12	40	<10	184	<0.05	Well #2
Dawson	M-R	830	251	118	5.6	520	>2	Well #1
		600	88	118	5.2	520	<0.01	Well #2
DuBois	M-R	880	57	98	38	460	<0.02	Main Well (3 wells)
Elk Creek	M-R	472	20	58	<10	364	0.01	Park Well (2 wells)
Falls City	M-T	220	18	104	<10	168	0.25	Dist. System (10 wells)
Firth	M-R	470	18	37	<10	240	<0.05	Park well
Humboldt	M-R	524	12	18	<10	284	0	New well (3 wells)
		346	10	24	<10	332	<0.01	Spring
		338	16	16	10	284	<0.01	Park well
		422	39	322	0.6	1600	.67	South well
Panama	M-R	1,062	53	152	<10	248	0	Well #2 (2 wells)
Pawnee City	M-T	332	6	20	< 0.01	234	<0.02	North well(3 wells)
Salem	M-R	720	43	64	<10	528	1.32	Well #1
		724	65	64	<10	488	2.82	Well #2
Shubert	M-R	386	16	20	<10	386	0.47	Well #1 (2 wells)
Stella	M-R	278	16	12	<10	188	<0.01	Well #1 (1 well)
Sterling	M-R	350	.18	64	<10	244	<0.05	Well #1
		450	20	40	<10	368	<0.05	Well #2
Table Rock	M-R	944	112	100	34	600	<0.01	Well #1
		302	10	40	<10	212	0.25	Well #2
Tecumseh	M-R	510	10	144	2.6	304	0.1	Well #1 (3 wells)
Verdon	M-R	562	41	90	<10	292	<0.01	Well #1 (1 well)
KANSAS								
Bern	M-R	468	13	44	0.4	314	3.2	Deep wells
Corning	M-R	504	7	183	1.4	434	3.2	Shallow well
Hiawatha	M-R	282	7	13	15	238	0.08	Springs & wells
Morrill	M-R	433	14	43	44	381	0.04	Shallow wells
Reserve	M-R	508	58	81	41	366	0.03	Shallow well
Sabetha	M-T	318	17	95	0.4	246	0.03	Impounded Reservoir
Seneca	M-T	421	9	33	24	358	0.02	3 springs & 2 wells

*M - municipal; R - raw; T - treated

Exhibit No. 5

Basic Data on Sources of Pollution[16/]

Nemaha River Basin Study Area (Nebraska & Kansas)

Municipality	River Miles Above Mouth	1960 Pop.	1963 Sewered Population	P.E.(BOD) Before Treatment	Nature of Waste	Treatment Provided	P.E.(BOD) Discharged	Water Course
NEBRASKA								
Adams	M511.2-40.5-80	387	350E	350	Domestic	Secondary	90E	N.Fork Big Nemaha R.
Falls City	M511.2-26.2	5,598	5,500E	5,500E	*	None	5,500E	Big Nemaha River
Filley	MR511.2-26E-80E	149	140	140	Domestic	Lagoon	0	Mud Creek
Firth	MR611.6-26.4-85E	277	270	270	Domestic	Lagoon	0	Middle Branch Big Nemaha
Humboldt	M511.2-40.5-26.4	1,322	1,300E	1,300	Domestic	None	1,300E	N.Fork Big Nemaha R.
Pawnee City	M511.2-40.5-46-19	1,343	1,300E	1,300	Domestic	Secondary	300	Turkey Creek
Sterling	M511.2-40.5-70.3	471	200	200	Domestic	Imhoff	150E	N.Fork Big Nemaha R.
Tecumseh	511.2-40.5-56.6	1,887	1,550	1,550	Domestic	None	1,550	N. Fork Big Nemaha R.
KANSAS								
Fairview	511.2-23.0-21.0E	272	315	390E	Domestic	Lagoon	30	Walnut Creek
Morrill	M511.2-23.0-16.0	299	300	290E	Domestic	Secondary	30	Terrapin Ck. to Walnut Creek
North Plant Sabetha	M511.2-26.2-18.0	2,318	1,300	1,300E	Domestic	Secondary	200	Pony Creek
Seneca	M511.2-40.5-53.1	2,072	2,000	2,100	Domestic	Septic Tank	1,900E	S.Fork of Big Nemaha

E - Estimated
*Data not available.

Exhibit No. 6

Summary of Alternates for Water Quality Control

Nemaha River Basin Study Area (Nebraska and Kansas)

Location	Item	Construction Cost $	Year of First Need	Amortized @ 3% for 100 years	Annual Value Discounted @ 3% to 1960 ($)
Seneca, Kansas	Holding Pond	80,000	2000	2,500	770
	Annual Operation & Maintenance	2,500*	2000	--	670
				"Seneca" total	1,440
Sabetha, Kansas	Pipeline & Pumps	318,000	1960	10,000	10,000
	Pipeline & Pumps	443,000	2010	14,000	3,200
	Annual Operation & Maintenance	3,000*	1960	--	3,000
				"Sabetha" total	16,200
		"Seneca & Sabetha" grand total			17,640

*Annual Operation & Maintenance Costs

Exhibit No. 6